US006234771B1

(12) **United States Patent**
Carey et al.

(10) **Patent No.: US 6,234,771 B1**
(45) **Date of Patent: May 22, 2001**

(54) **PRECISION PUMPING DEVICE**

(75) Inventors: **Glen A. Carey**, Grafton; **William R. Downing**, Elyria; **David J. Lapeus**, Medina; **Randi L. Richey**, Wellington; **Mary Beth Whitesel**, Grafton, all of OH (US)

(73) Assignee: **Bayer Corporation**, Tarrytown, NY (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/322,354**

(22) Filed: **May 28, 1999**

Related U.S. Application Data

(60) Provisional application No. 60/087,718, filed on Jun. 2, 1998.

(51) **Int. Cl.**[7] **F04B 17/00**
(52) **U.S. Cl.** **417/415**; 417/360
(58) **Field of Search** 417/360, 212, 417/415

(56) **References Cited**

U.S. PATENT DOCUMENTS

1,695,305		12/1928	Upton	92/13.6
3,036,529		5/1962	Archer	103/168
3,155,041		11/1964	Green	103/37
3,447,479	*	6/1969	Rosenberg	103/153
3,556,679	*	1/1971	Middlebusher et al.	417/63
4,089,624		5/1978	Nichols et al.	417/362
4,276,003	*	6/1981	Perkins et al.	417/415
4,566,868		1/1986	Menzies	417/572
4,715,791		12/1987	Berlin et al.	417/274
4,793,776	*	12/1988	Thistle et al.	417/360
4,799,866	*	1/1989	Faeser et al.	417/415
4,922,900	*	5/1990	Kiske et al.	128/202.27
4,941,808	*	7/1990	Qureshi et al.	417/415
5,201,851	*	4/1993	Holmstrom	417/415
5,312,233	*	5/1994	Tanny et al.	417/316
5,540,562		7/1996	Giter	417/254
5,567,122	*	10/1996	Schulte	417/214

FOREIGN PATENT DOCUMENTS

2053724A	2/1981	(GB)	B01D/13/00

OTHER PUBLICATIONS

Sanwa Tsusho Co., Ltd., Tokyo, Japan, Micro Pumps OEM Models, Jun. 16, 1998.

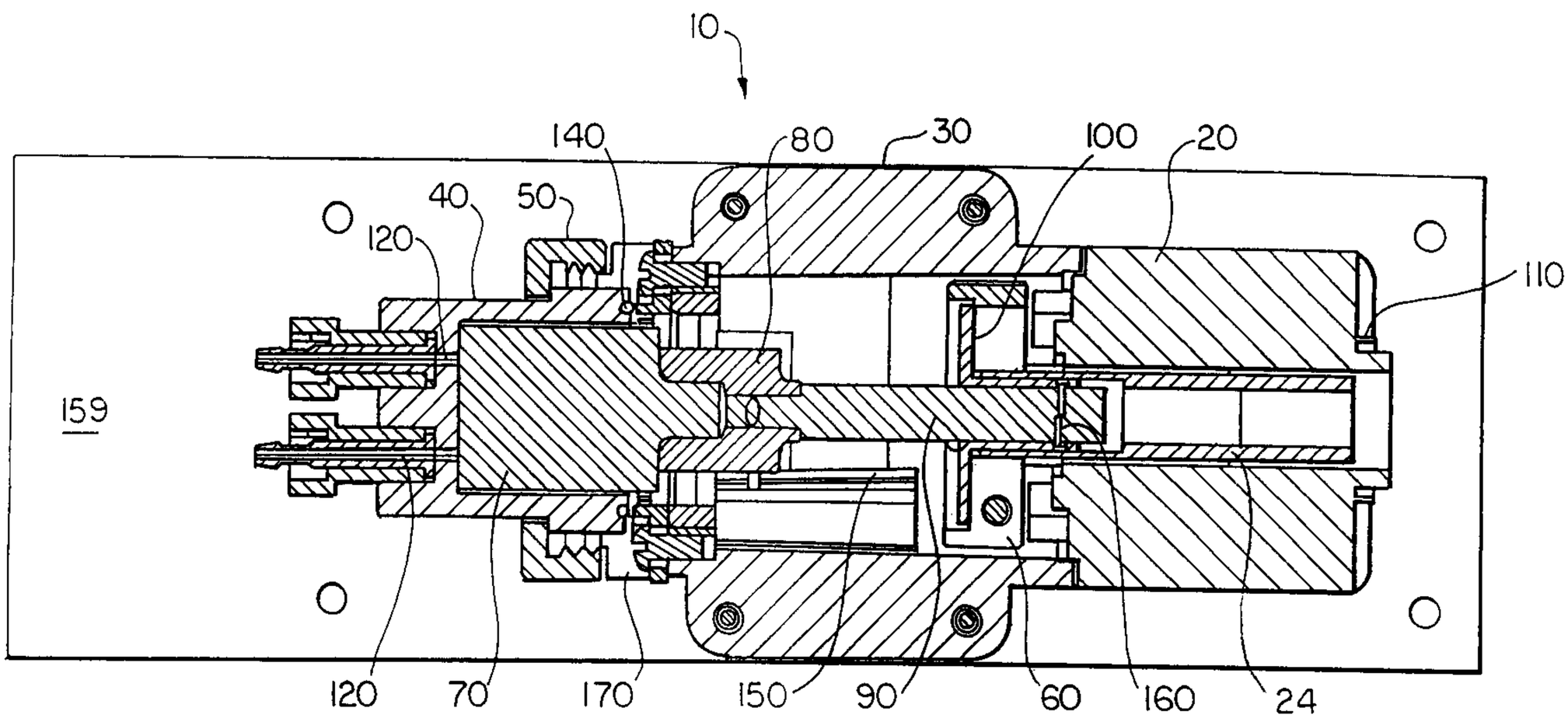
* cited by examiner

Primary Examiner—Timothy S. Thorpe
Assistant Examiner—Timothy P Solak
(74) *Attorney, Agent, or Firm*—Weingarten, Schurgin, Gagnebin & Hayes LLP

(57) **ABSTRACT**

A precision pumping device for aspirating and dispensing different volumes of fluid is presented. The precision pumping device comprises a housing with integral anti-rotation guides, a stepper motor which drives a fine pitch lead screw, a coupling for linking the piston to the leadscrew, an anti-backlash leadscrew follower, a split hub clamp nut, and a nut for securing the chamber to the housing. A seal is provided which seals around the piston and against the chamber, as is an o-ring that is set into a groove in the chamber and seals against a flange of the seal. The precision pumping device further includes a piston and a chamber for receiving at least a portion of the piston therein. The piston and chamber are of different sizes for aspirating and dispensing different volumes of fluid. The chamber can include a single port or multiple ports. Due to the self-aligning features and the reduced number of parts, the pump can be easily changed from aspirating and dispensing a first volume of fluid to aspirating and dispensing a second volume of fluid.

11 Claims, 10 Drawing Sheets



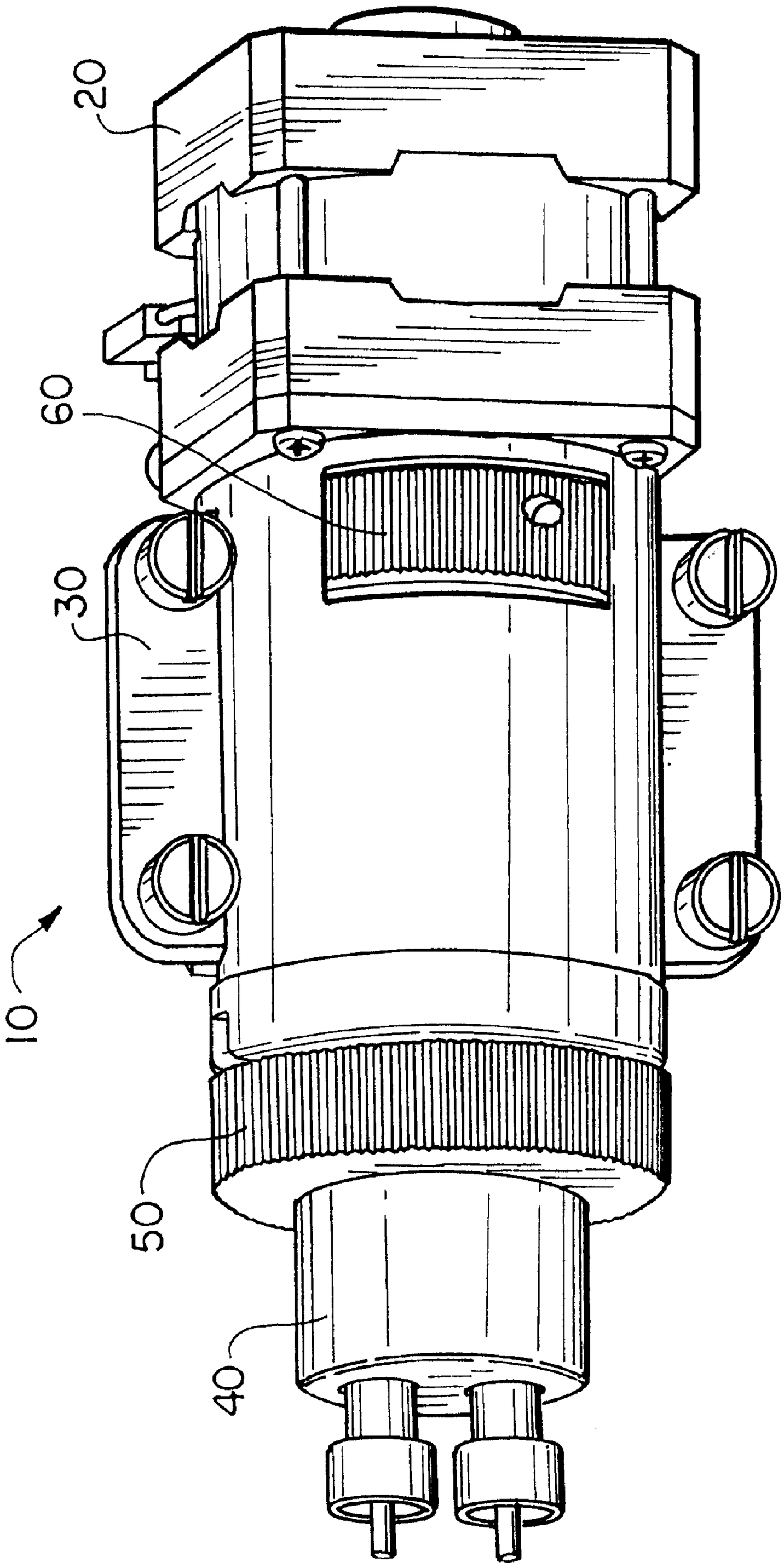


FIG. 1

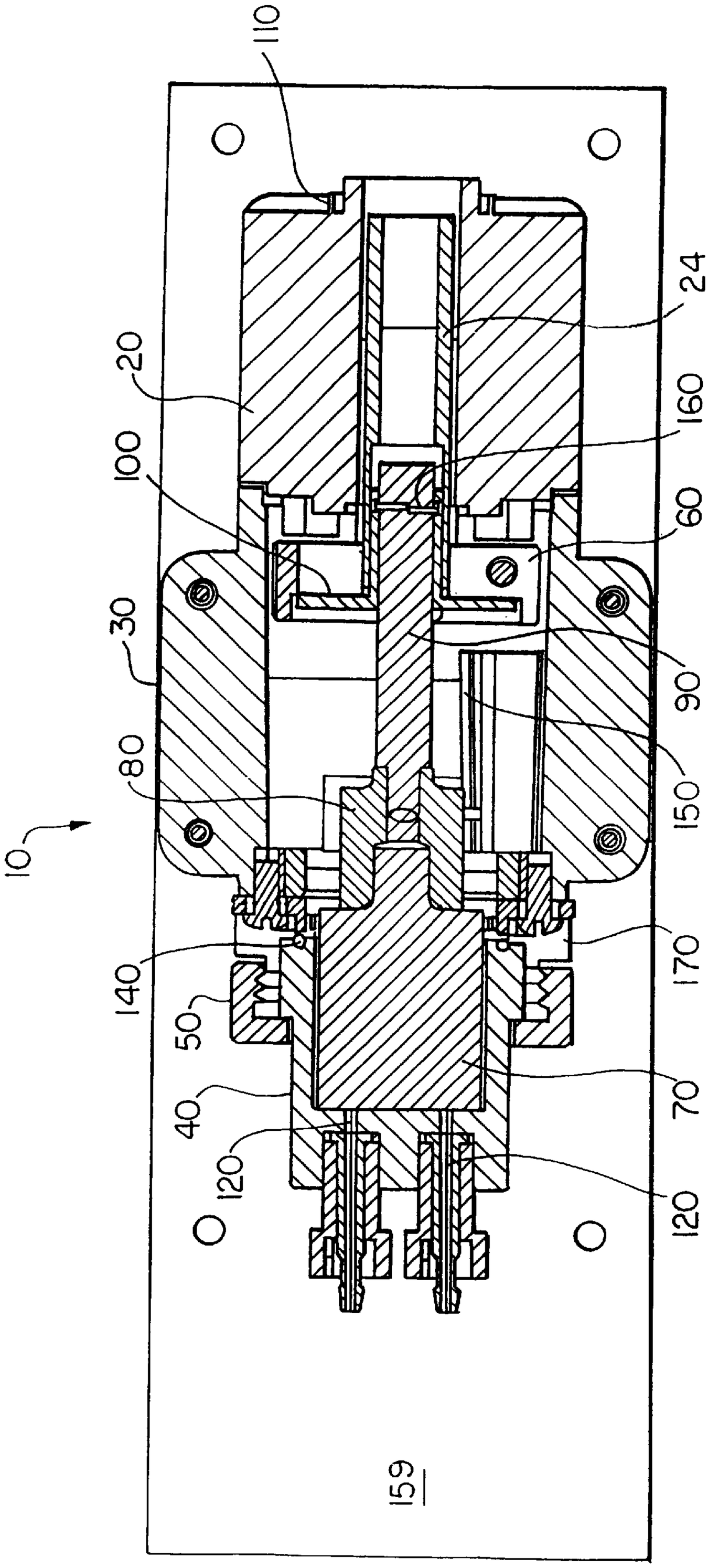


FIG. 2

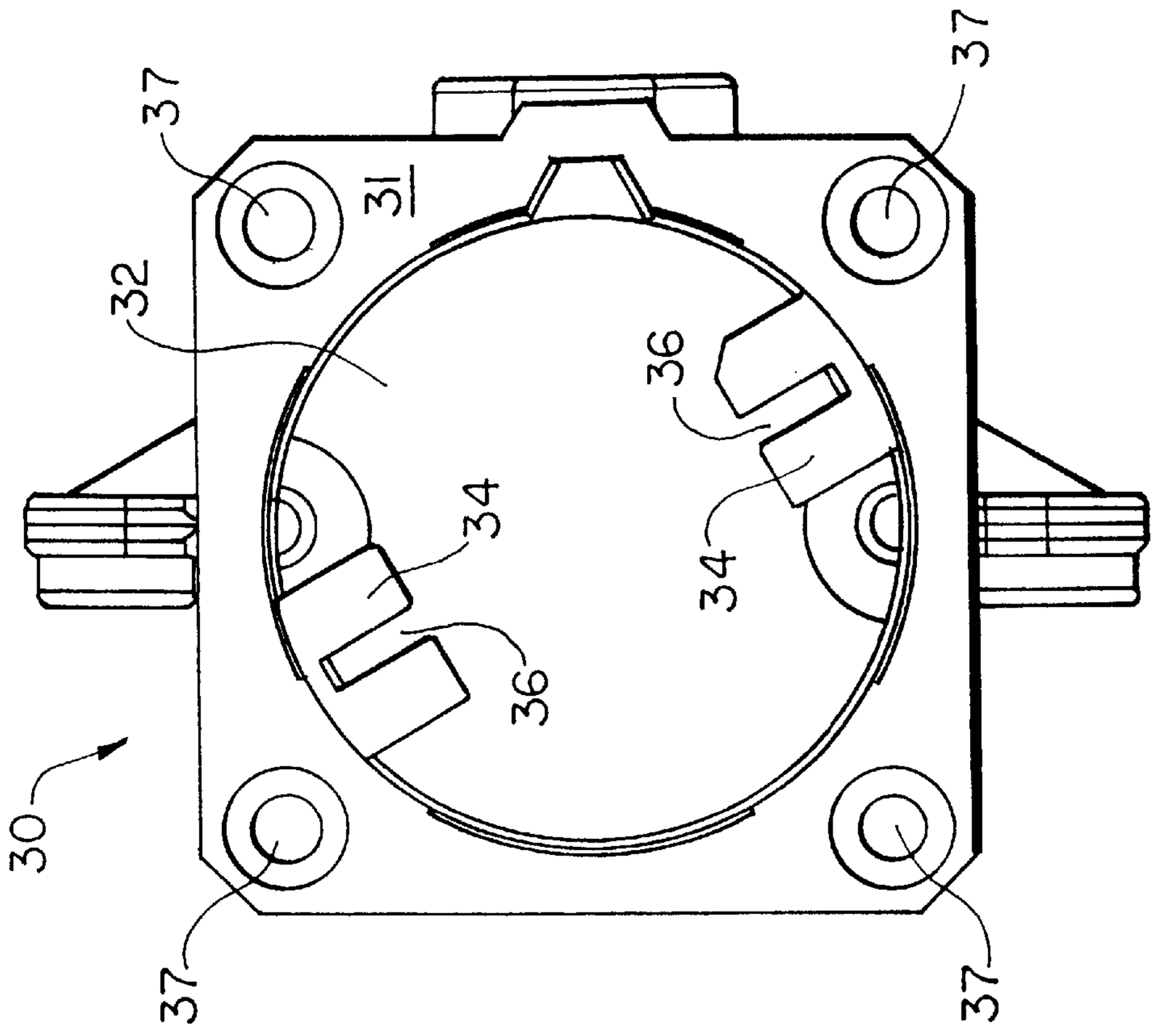


FIG. 3A

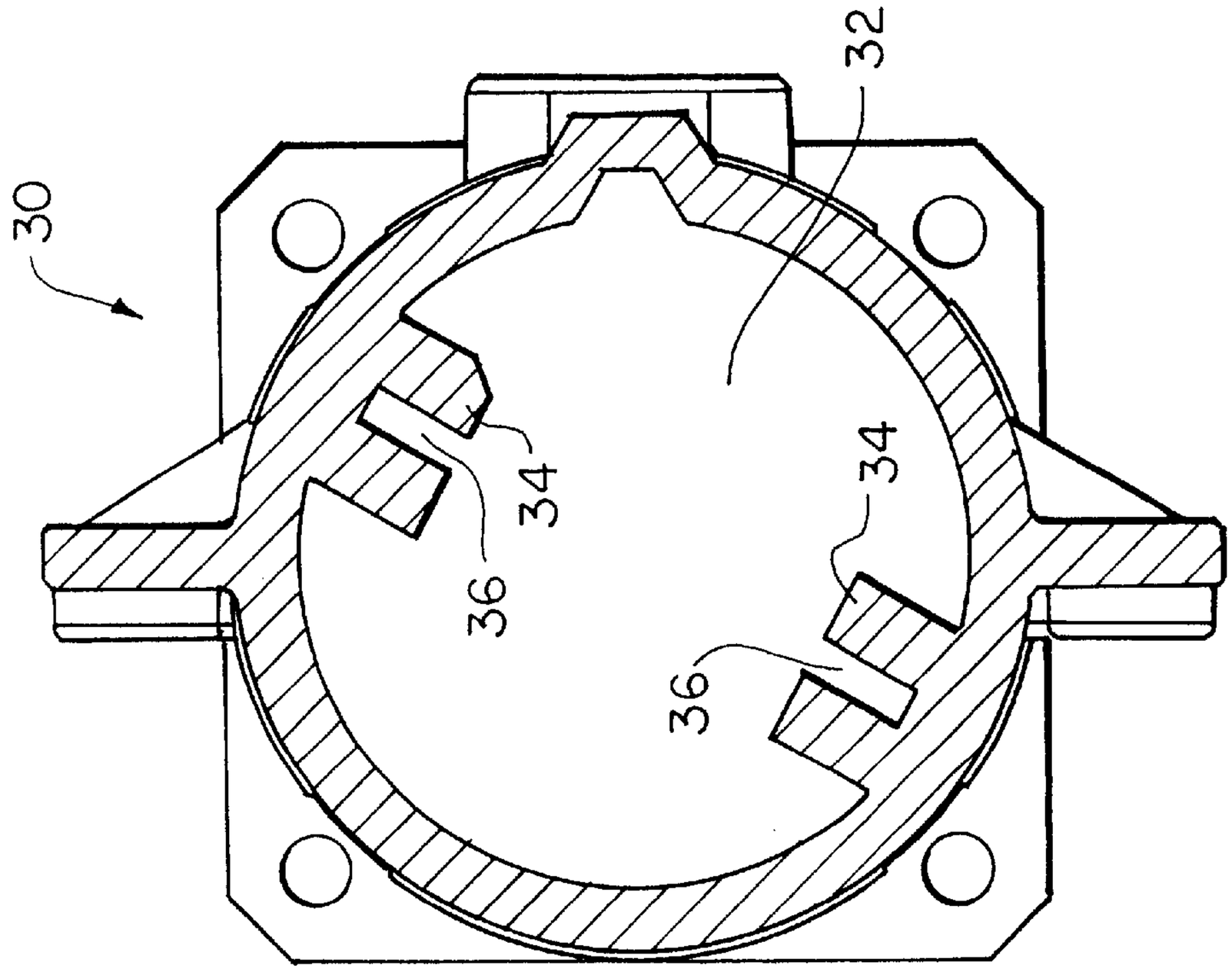


FIG. 3B

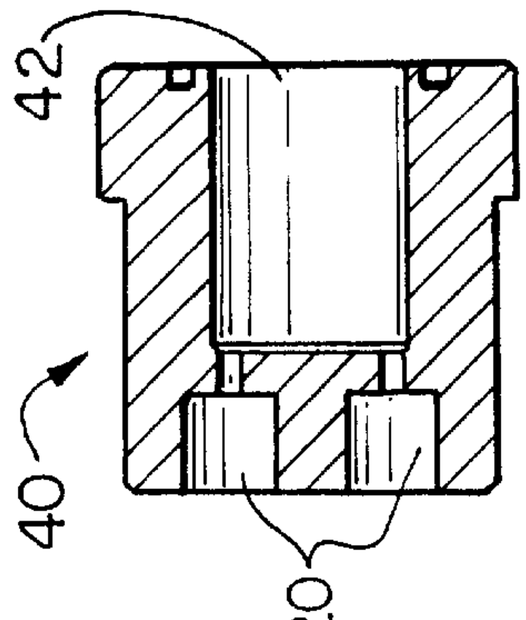


FIG. 4B

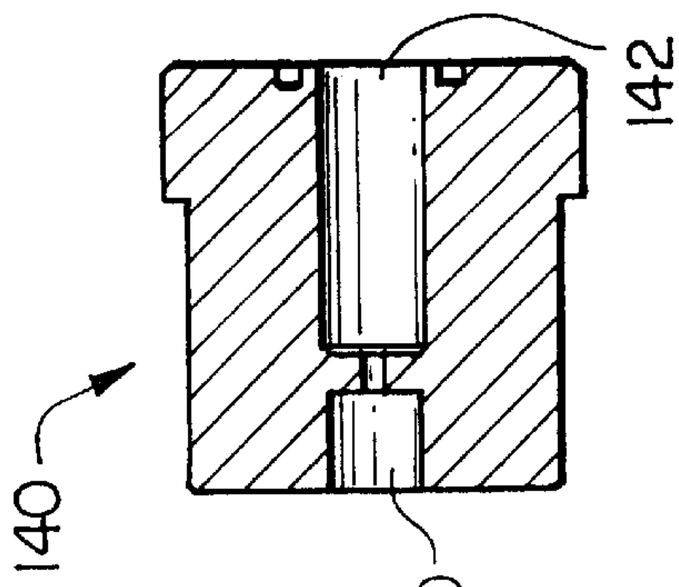


FIG. 4D

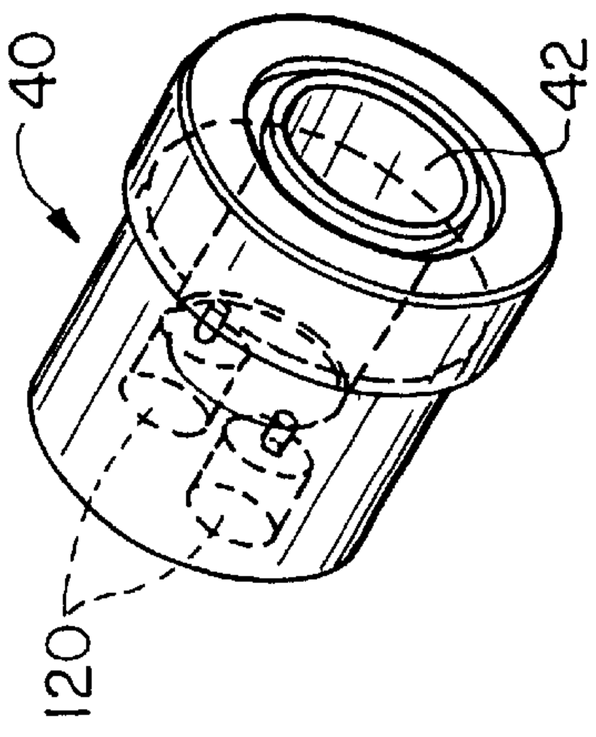


FIG. 4A

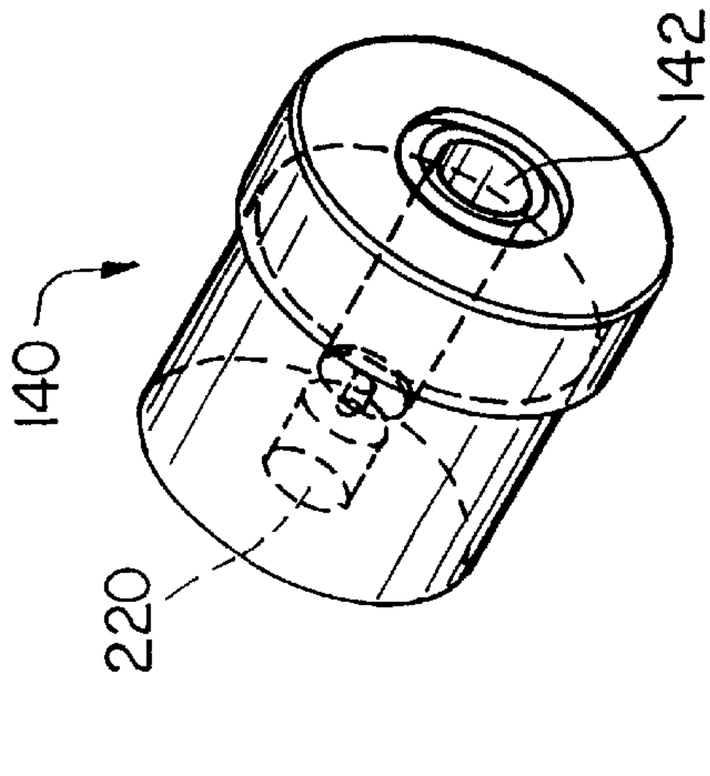


FIG. 4C

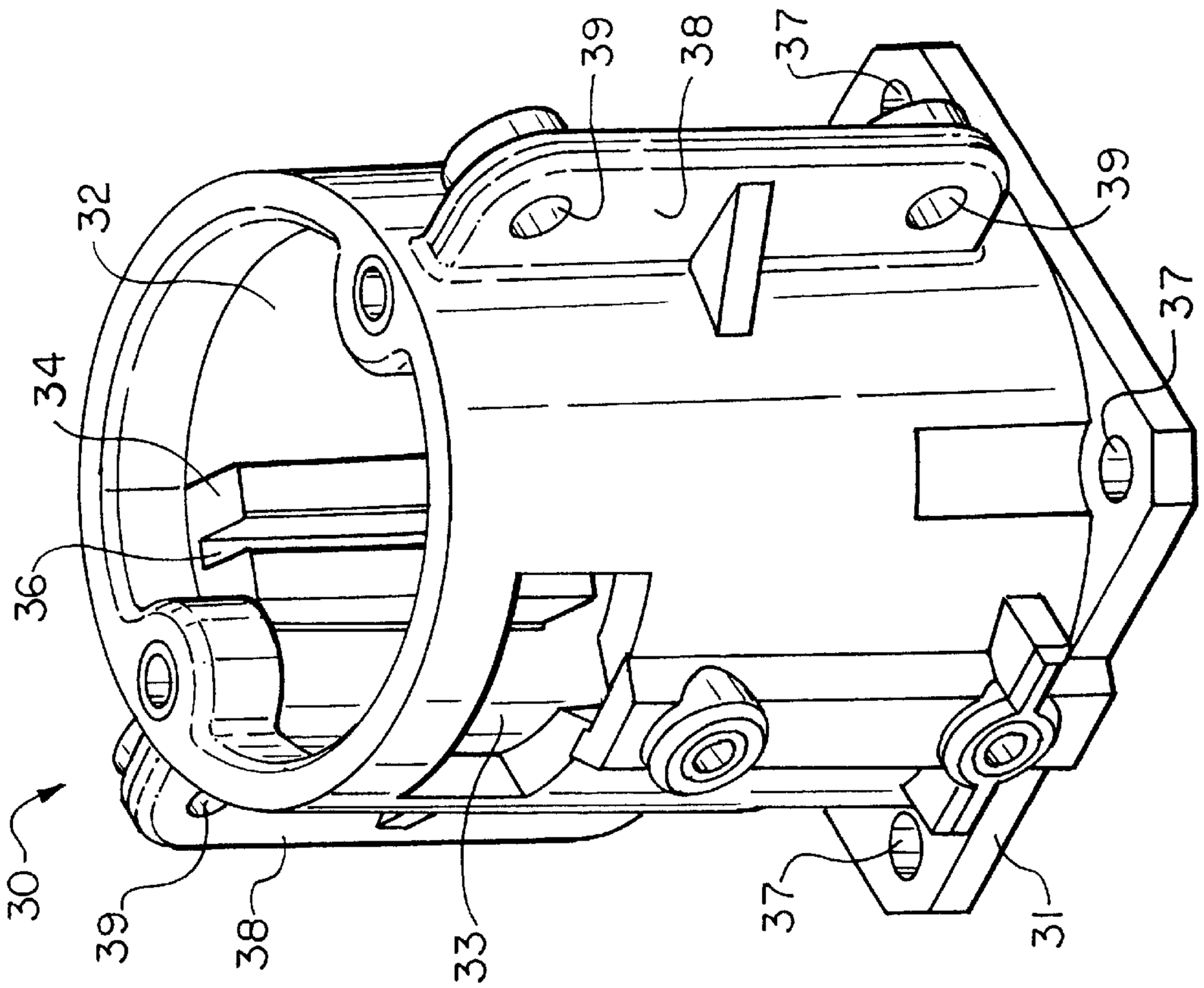


FIG. 3C

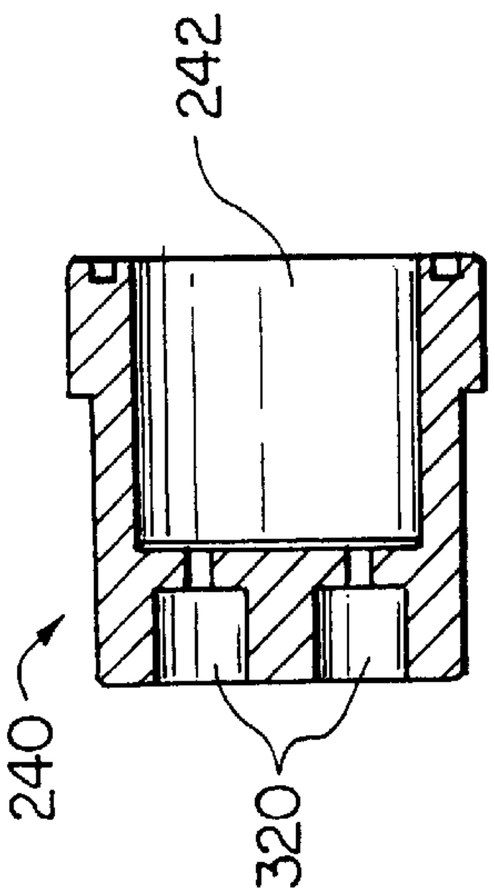


FIG. 4F

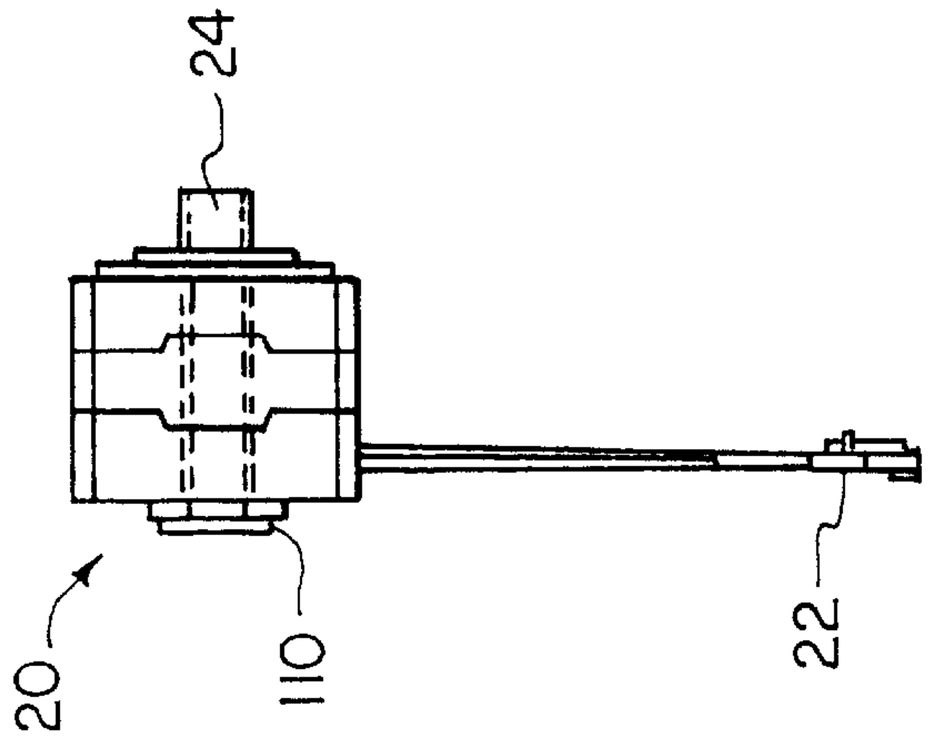


FIG. 5C

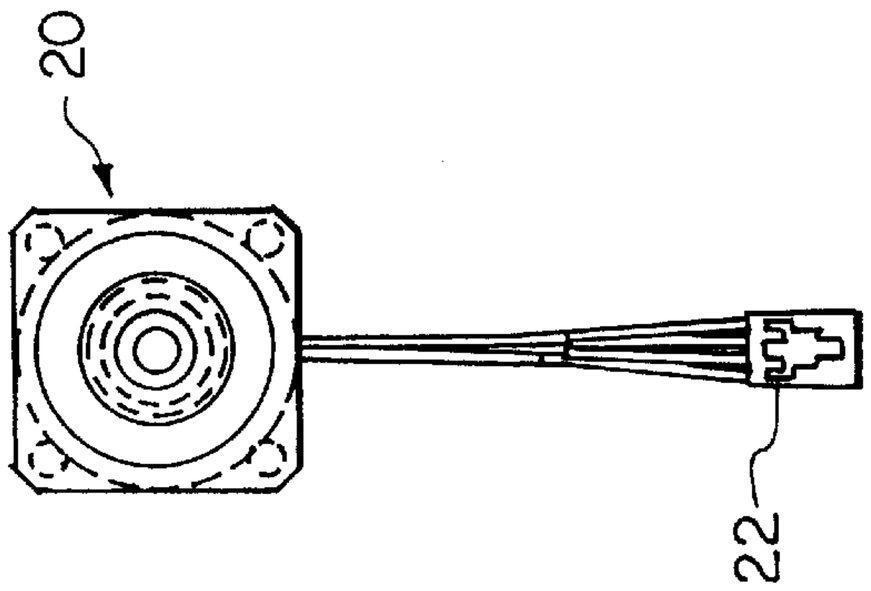


FIG. 5B

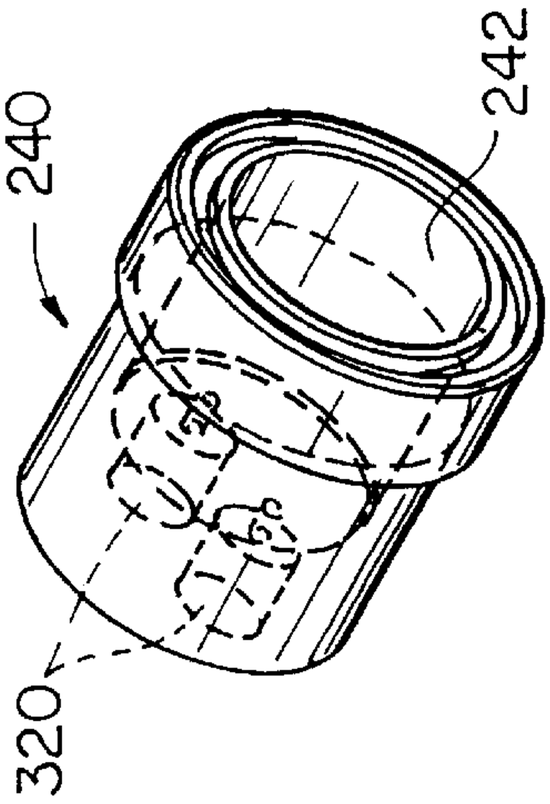


FIG. 4E

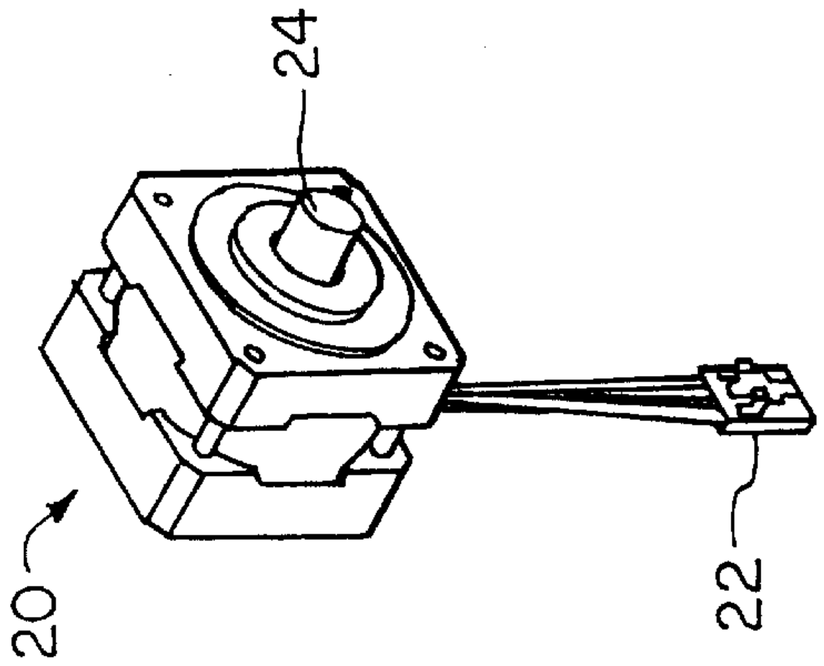


FIG. 5A

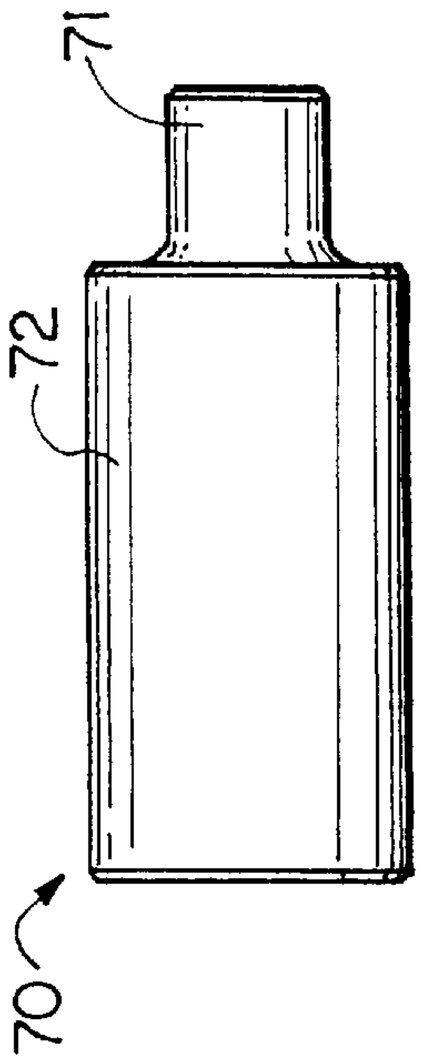


FIG. 6C

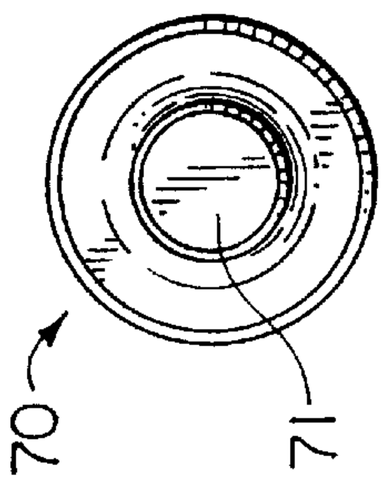


FIG. 6B

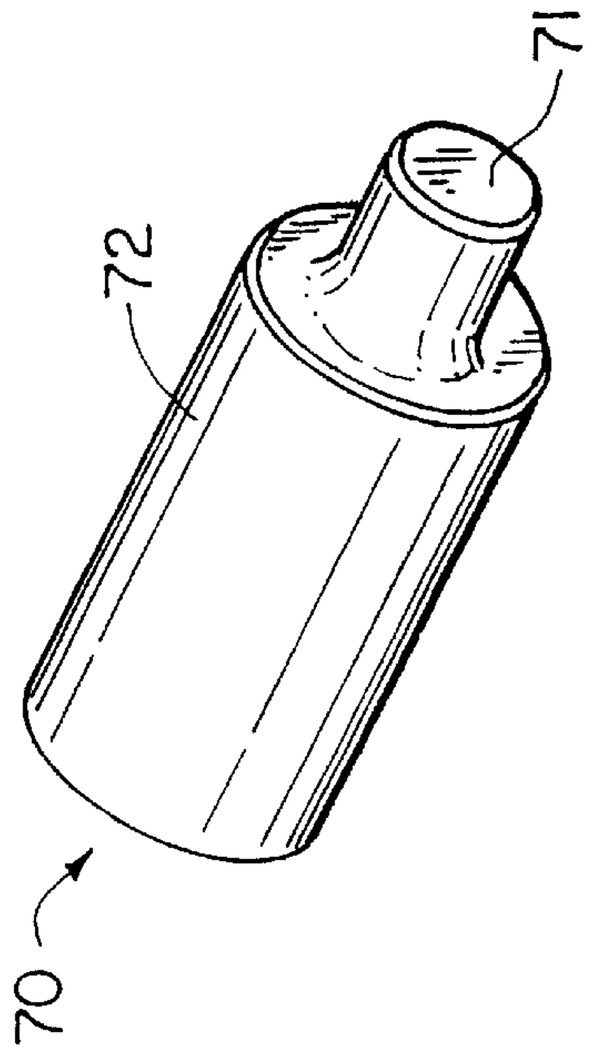


FIG. 6A

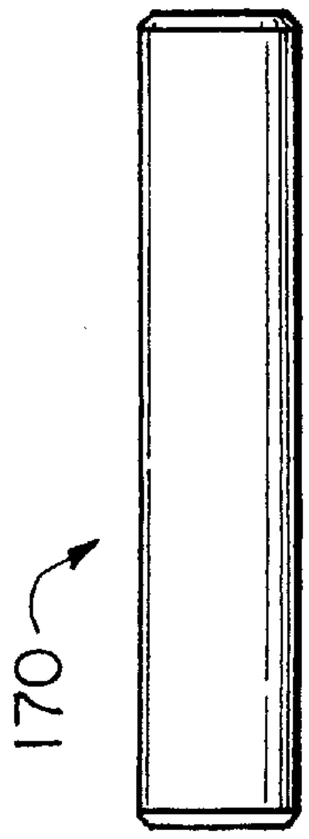


FIG. 6F

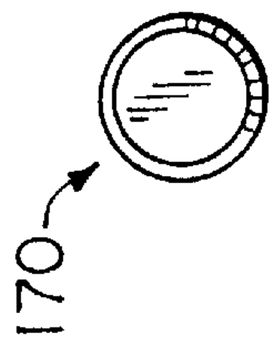


FIG. 6E

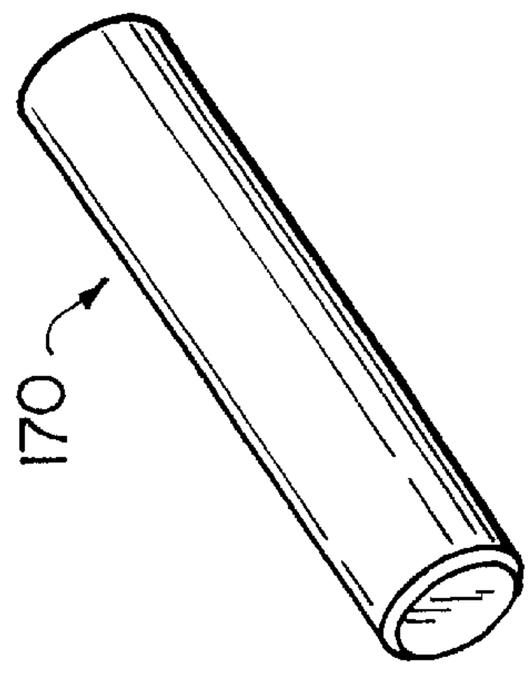


FIG. 6D

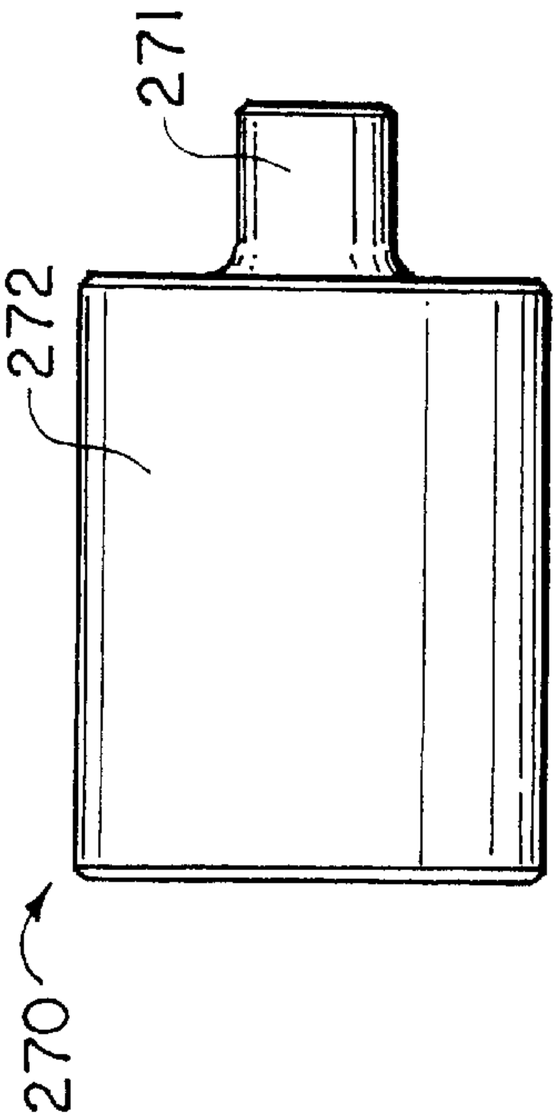


FIG. 6I

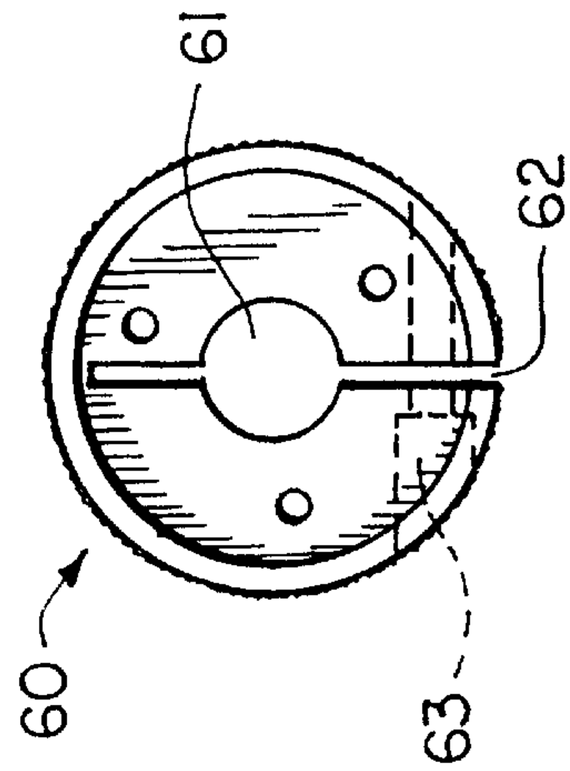


FIG. 7C

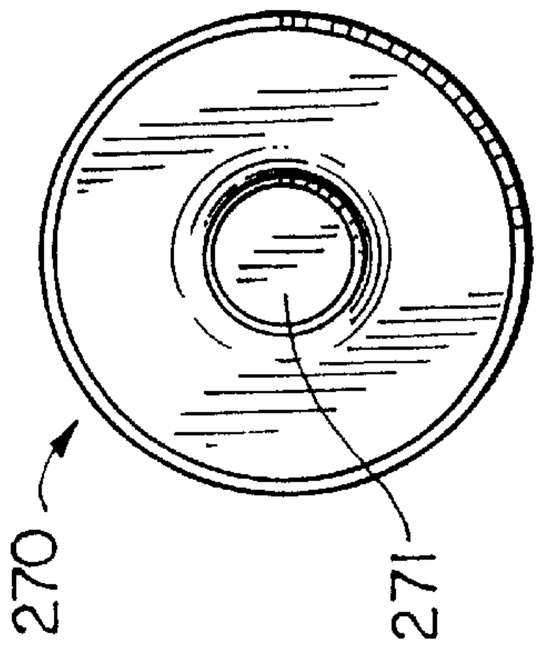


FIG. 6H

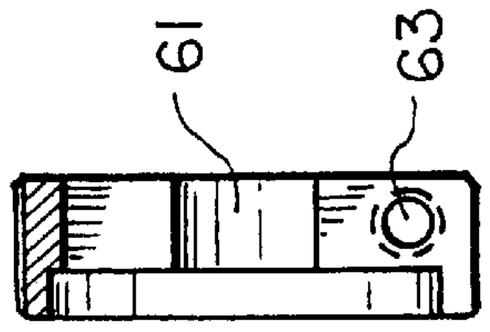


FIG. 7B

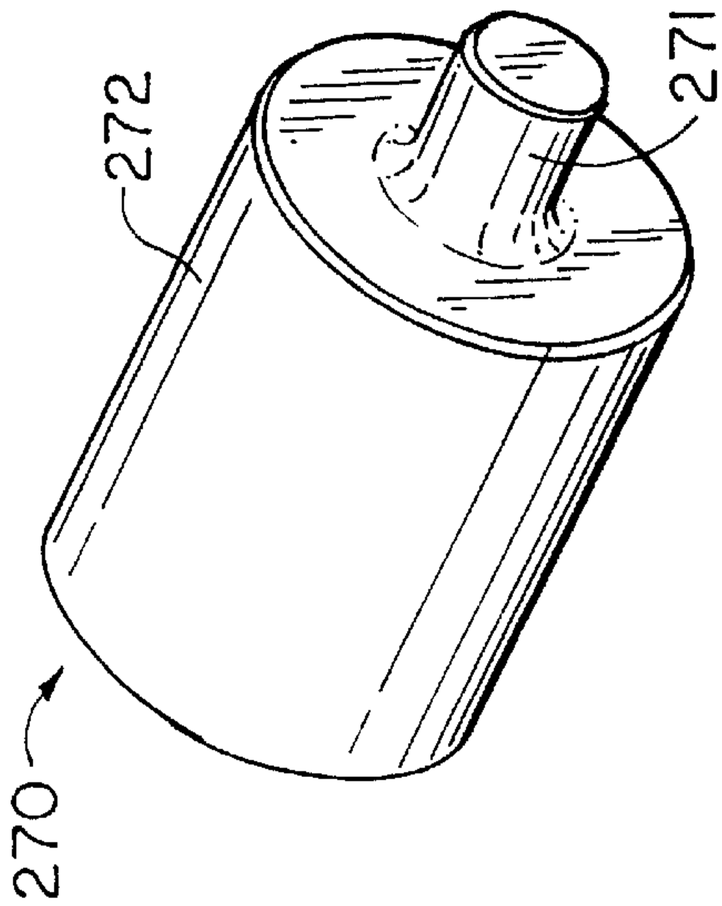


FIG. 6G

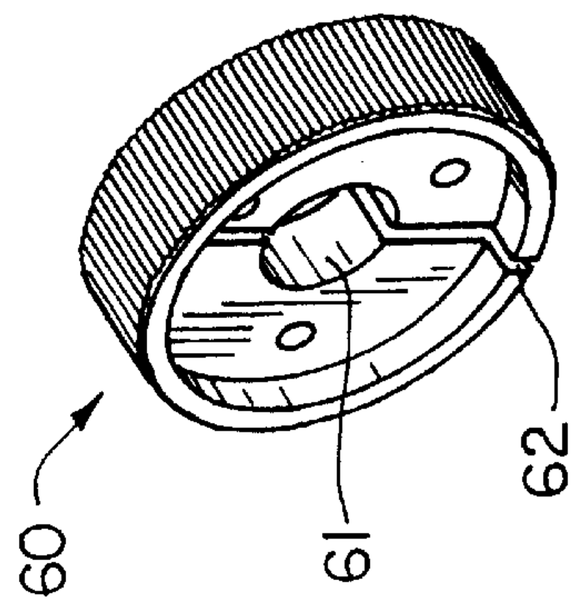


FIG. 7A

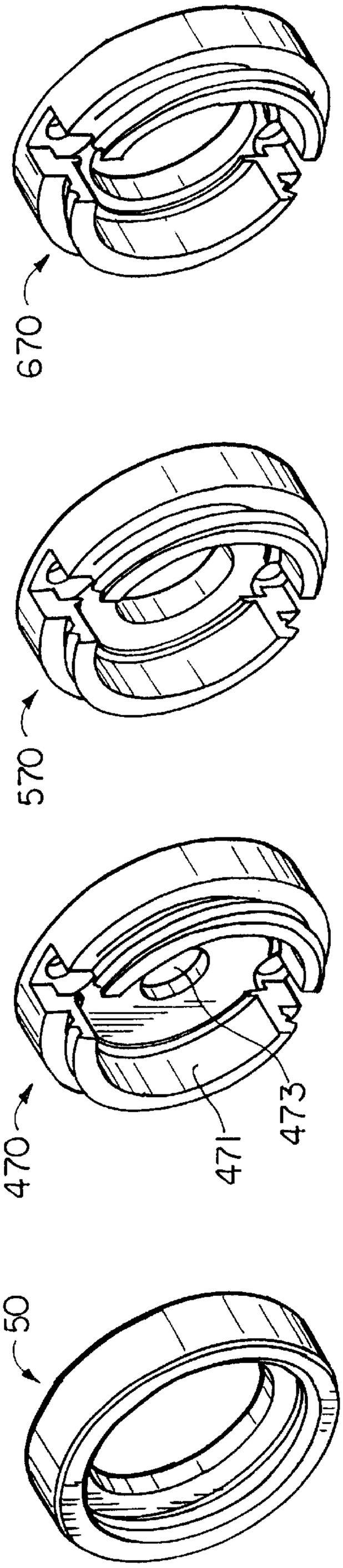


FIG. 8A

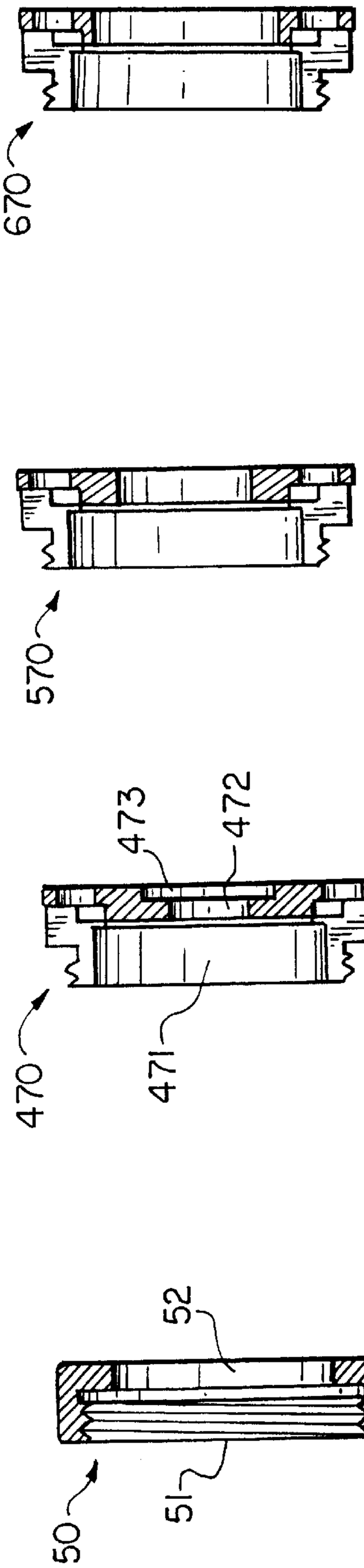


FIG. 8B

FIG. 9A

FIG. 9B

FIG. 9C

FIG. 9D

FIG. 9E

FIG. 9F

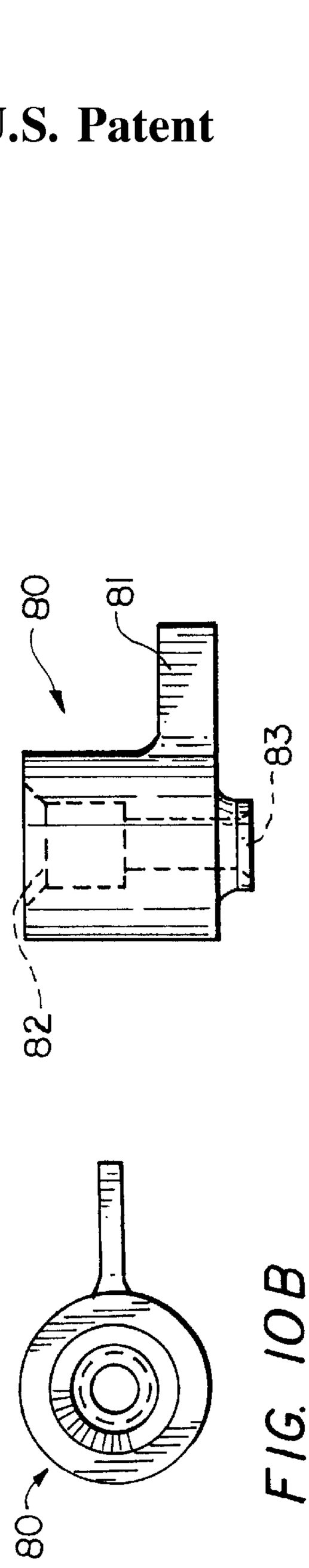


FIG. 10C

FIG. 10B

FIG. 11B

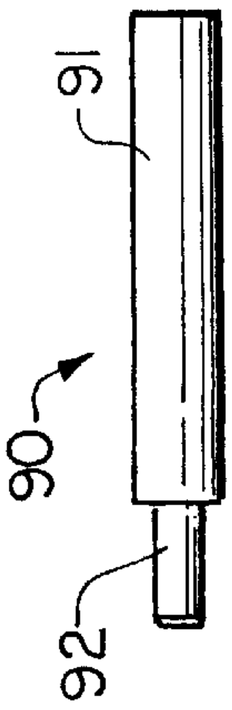


FIG. 11A

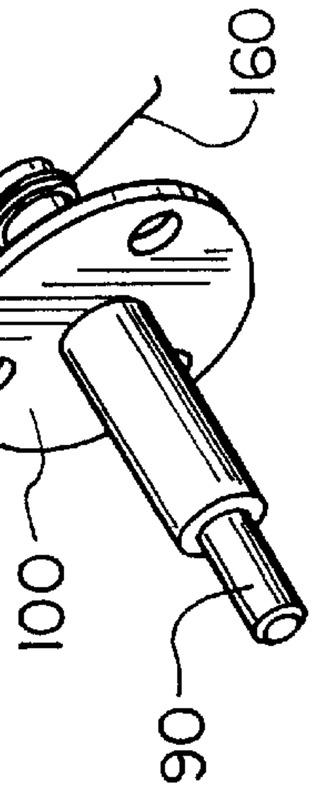


FIG. 14

FIG. 12A

FIG. 12B

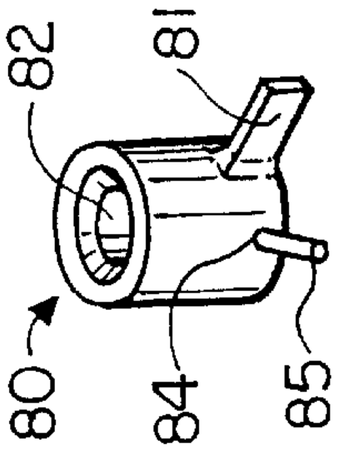


FIG. 10A

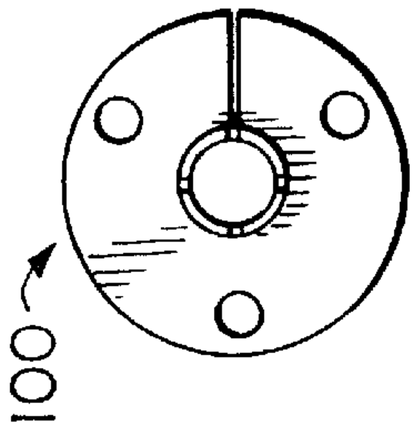


FIG. 13A

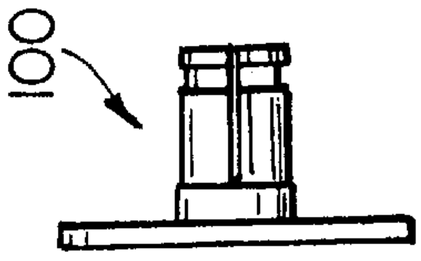


FIG. 13B

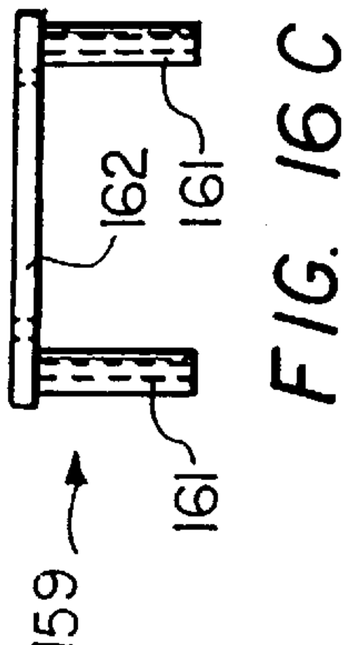


FIG. 16C

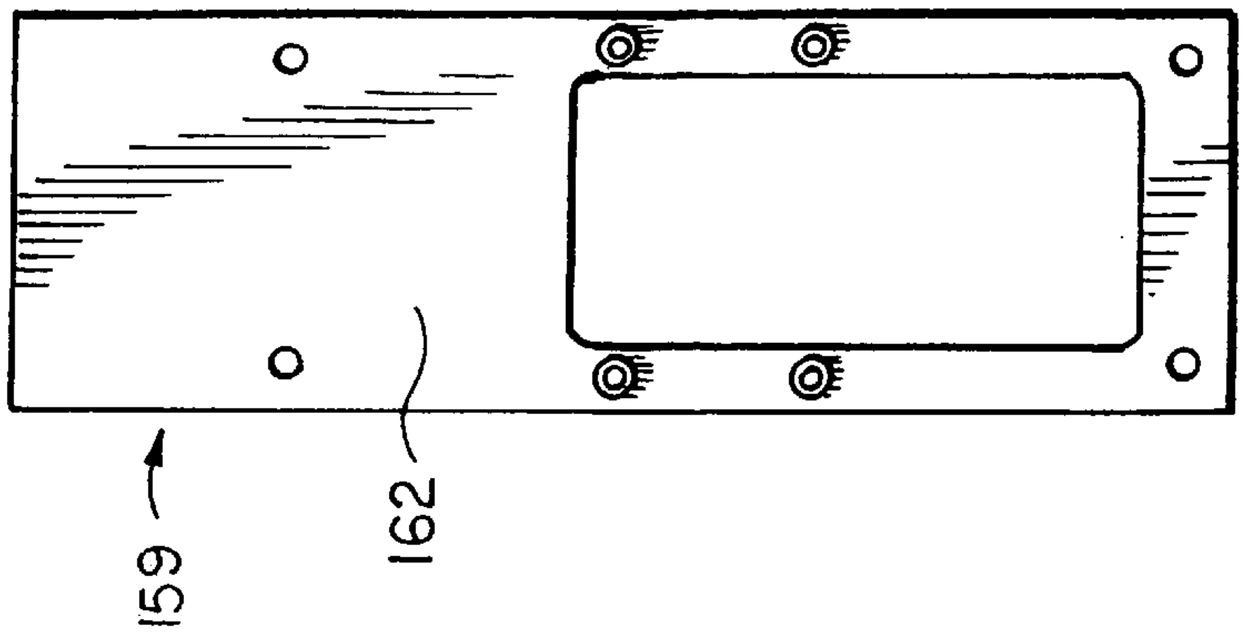


FIG. 16B

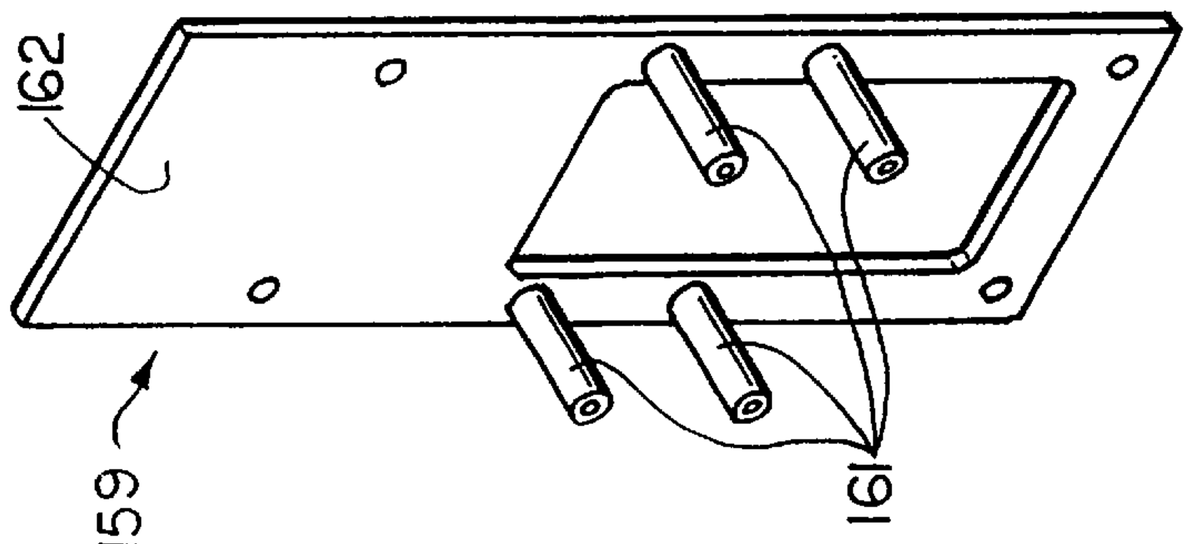


FIG. 16A

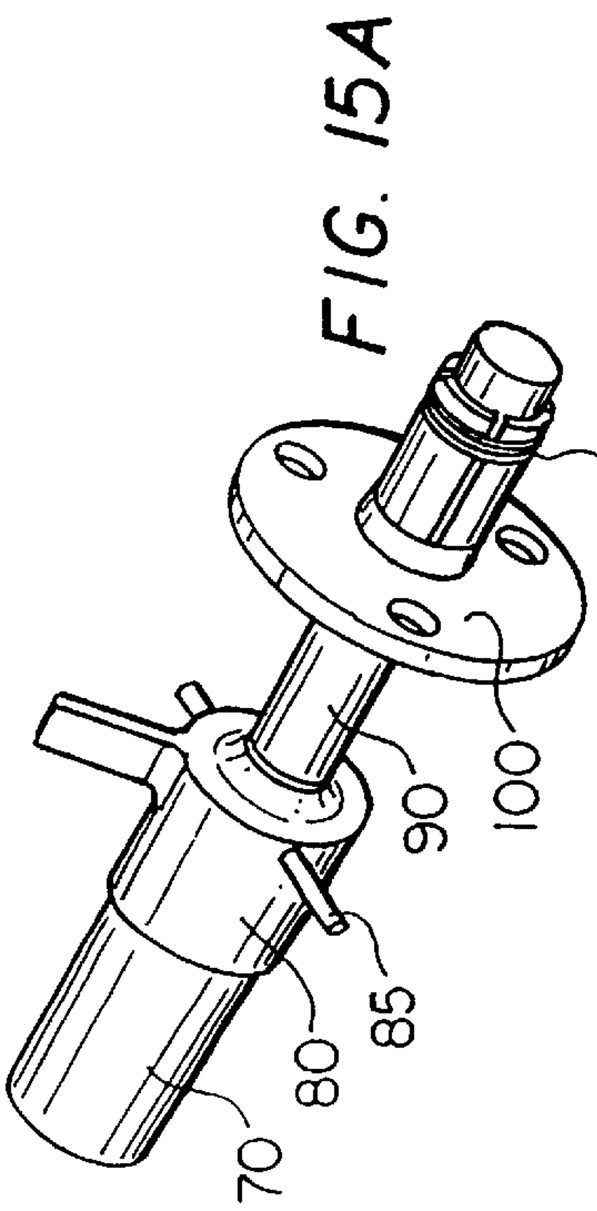


FIG. 15A

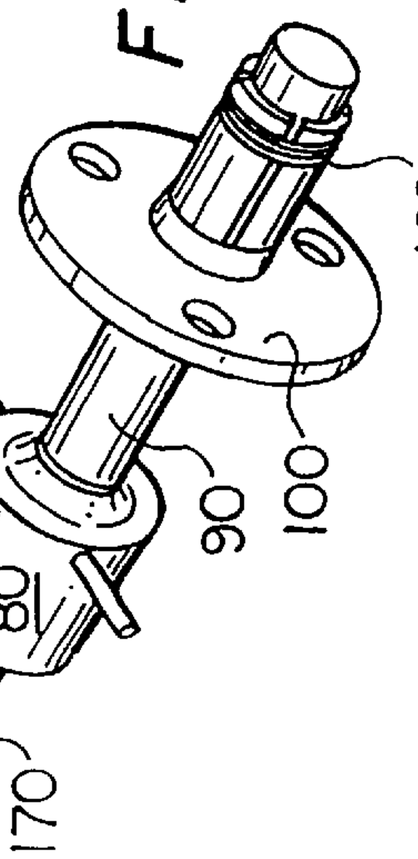


FIG. 15B

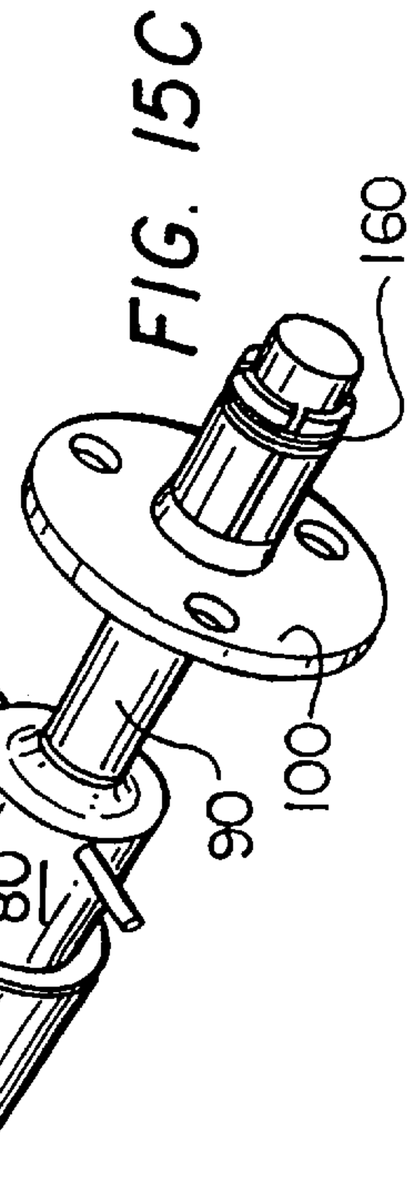


FIG. 15C

PRECISION PUMPING DEVICE

RELATED APPLICATIONS

This application claims priority under 35 U.S.C. § 119(e) to provisional patent application Ser. No. 60/087,718, filed Jun. 2, 1998, the disclosure of which is hereby incorporated by reference.

STATEMENT OF FEDERALLY SPONSORED RESEARCH

Not Applicable

BACKGROUND OF THE INVENTION

Pumps are used to dispense and aspirate fluids. When it is desirable to repeatedly dispense and/or aspirate small quantities of fluid, the pump must be made to provide precise dispensing and aspirating operations. Pumps typically comprise many pieces, which make the pump difficult to manufacture and assemble. Additionally, the multiple pieces have varying tolerances that affect the accuracy and precision of the pump.

Sanwa Tsusho Co., LTD. Tokyo, Japan produces a micro pump. The pump of Sanwa Tsusho Co., LTD. has a piston seal that includes a washing port, does not include an anti-backlash follower and does not include a manual adjustment for changing the position of the piston within the pump.

It would be desirable to have a precision pump which includes a minimal amount of parts, which is simple to manufacture and assemble, and which provides a high degree of accuracy for a large number of aspirating and/or dispensing operations.

SUMMARY OF THE INVENTION

A precision pumping device for aspirating and dispensing different volumes of fluid is presented. The precision pumping device comprises a housing with integral anti-rotation guides, a stepper motor which drives a fine pitch lead screw, a coupling for linking the piston to the leadscrew, an anti-backlash leadscrew follower, a split hub clamp nut, and a nut for securing the chamber to the housing. A seal is provided which seals around the piston and against the chamber, as is an o-ring that is set into a groove in the chamber and seals against a flange of the seal. A piston is driven into and out of a cooperating chamber to provide aspirating and dispensing of fluids. By way of the anti-rotation guides, the fine pitch leadscrew, the anti-backlash leadscrew follower, and other parts of the pump, precise volumes of fluid are aspirated and dispensed. The precision pumping device may further include sets of cooperating pistons and chambers of different sizes for aspirating and dispensing different volumes of fluid. The chamber can include a single port or multiple ports. Due to the self-aligning features and the reduced number of parts, the pump can be easily changed from precisely aspirating and dispensing a first volume of fluid to precisely aspirating and dispensing a second volume of fluid.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be better understood by referring to the detailed description taken in conjunction with the following drawings, in which:

FIG. **1** is a view of the precision pumping device of the present invention;

FIG. **2** is a cross-sectional side view of the precision pump of FIG. **1**;

FIG. **3**A is a top view of the housing of the precision pump of FIG. **1**;

FIG. **3**B is a cross-sectional top view of the housing of FIG. **3**A;

FIG. **3**C is a perspective view of the housing of FIG. **3**A;

FIG. **4**A is a perspective view of a first chamber;

FIG. **4**B is a cross-sectional side view of the first chamber of FIG. **4**A;

FIG. **4**C is a perspective view of a second chamber;

FIG. **4**D is a cross-sectional side view of the second chamber of FIG. **4**C;

FIG. **4**E is a perspective view of a third chamber;

FIG. **4**F is a cross-sectional side view of the third chamber of FIG. **4**E;

FIG. **5**A is a perspective view of a motor;

FIG. **5**B is a frontal view of the motor of FIG. **5**A;

FIG. **5**C is a side view of the motor of FIG. **5**A;

FIG. **6**A is a perspective view of a first piston;

FIG. **6**B is an end view of the first piston of FIG. **6**A;

FIG. **6**C is a side view of the first piston of FIG. **6**A;

FIG. **6**D is a perspective view of a second piston;

FIG. **6**E is an end view of the second piston of FIG. **6**D;

FIG. **6**F is a side view of the second piston of FIG. **6**D;

FIG. **6**G is a perspective view of a third piston;

FIG. **6**H is an end view of the third piston of FIG. **6**G;

FIG. **6**I is a side view of the third piston of FIG. **6**G;

FIG. **7**A is a perspective view of a split hub clamp nut;

FIG. **7**B is a cross-sectional side view of the split hub clamp nut of FIG. **7**A;

FIG. **7**C is an end view of the split hub clamp nut of FIG. **7**A;

FIG. **8**A is a perspective view of the nut;

FIG. **8**B is a cross-sectional side view of the nut of FIG. **8**A;

FIG. **9**A is a perspective view of a first seal;

FIG. **9**B is a cross-sectional side view of the seal of FIG. **9**A;

FIG. **9**C is a perspective view of a second seal;

FIG. **9**D is a cross-sectional side view of the seal of FIG. **9**C;

FIG. **9**E is a perspective view of a third seal;

FIG. **9**F is a cross-sectional side view of the seal of FIG. **9**E;

FIG. **10**A is a perspective view of a coupling;

FIG. **10**B is a top view of the coupling of FIG. **10**A;

FIG. **10**C is a side view of the coupling of FIG. **10**A;

FIG. **11**A is a side view of a leadscrew;

FIG. **11**B is an end view of the leadscrew of FIG. **11**A;

FIG. **12**A is a side view of a spring;

FIG. **12**B is an end view of the spring of FIG. **12**A;

FIG. **13**A is an end view of a follower;

FIG. **13**B is a side view of the follower of FIG. **13**A;

FIG. **14** is a perspective view of the leadscrew, follower and spring assembly;

FIG. **15**A is a perspective view of the first piston assembly;

FIG. **15**B is a perspective view of the second piston assembly;

FIG. **15**C is a perspective view of the third piston assembly;

FIG. **16**A is a perspective view of the mounting plate; and

FIG. **16**B is a top view of the mounting plate of FIG. **16**A.

FIG. **16**C is a side view of the mounting plate of FIG. **16**A.

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIG. **1**, a precision pumping device **10** for accurately aspirating and dispensing different volumes of liquid or gas is shown. The precision pumping device **10** includes a housing **30** having integral anti-rotation guides, a stepper motor **20**, a chamber **40**, a nut **50** for securing the chamber **40** to the housing **30**, and a split hub clamp nut **60** for manual positioning of an internal piston within the housing **30** and chamber **40**.

Shown in FIG. **2** is a top cross-sectional view of the precision pumping device **10**. In this figure the internal pieces of the pump **10** are shown. The stepper motor **20** drives a fine pitch leadscrew **90** that attaches to a first end of coupling **80**. The opposite end of coupling **80** attaches to piston **70**, such that the piston **70** is moveable by actuation of motor **20**. The leadscrew **90** also has an anti-backlash leadscrew follower **100** and a spring **160**.

Also shown in FIG. **2** is an end play lock nut **110** at one end of motor **20** as well as a seal **170** which is positioned between the nut **50** and the housing **30**. Seal **170** includes an o-ring **140** positioned between the chamber **40** and the seal **170**. Chamber **40** is shown here having multiple ports **120**.

Referring now to FIGS. **3**A–**3**C, housing **30** is shown. Housing **30** includes a central bore **32**. Disposed within the central bore **32** and integral with housing **30** is a pair of anti-rotation guides **34**. The anti-rotation guides **34** include a slotted opening **36** which receives a pin extending through the coupling **80**, and prevent the coupling **80** from rotating within the housing **30**. Housing **30** further includes a base portion **31** that contains a plurality of holes **37** for attaching the motor to the housing **30**. Housing **30** further includes a pair of mounting flanges **38** including mounting holes **39** for attaching the housing **30** to a support. Additionally, housing **30** includes a side opening **33** through which manual adjustment of the piston position is accomplished by rotating a split hub clamp nut, described in detail below. The housing and integral anti-rotation guides are manufactured from a wear resistant material such as LEXAN with TEFLON filler.

Shown in FIGS. **4**A–**4**F are chambers **40**, **140** and **240**. Each chamber has a substantially cylindrical shape and includes a respective cylindrical bore **42**, **142** and **242** extending a predetermined distance within the chamber for receiving a cooperating piston therein. Each respective cylindrical bore is configured, along with its respective cooperating piston, to provide for the aspirating and/or dispensing of different predetermined quantities of fluid. The chambers also include at least one port **120**, **220**, **320** extending from an end into the central bore, and allowing the central bore to be in fluid communication from within the chamber to external the chamber. Each chamber can include a single port or multiple ports **120**, **220**, **320**. A manifold may be utilized in place of the chamber, wherein the manifold receives the piston and is sealed against the flange of the seal which surrounds the piston.

Referring now to FIGS. **5**A–**5**C, motor **20** is shown. Motor **20** includes a power harness **22** that provides power to the motor and drives the rotor **24**. Rotor **24** also includes

an end play locknut **110** that is adjustable to remove any backlash between the fine pitch leadscrew and the motor **20**. As the locknut **110** is tightened against the stepper motor **20**, pressure is exerted on the rotor **24**, thus eliminating the opportunity for the rotor **24** to slide within the motor **20** when the direction of rotation of the motor **20** is reversed.

Referring now to FIGS. **6**A–**6**I, three different sized pistons are shown. FIGS. **6**A–**6**C show first piston **70**. Piston **70** includes two differently sized sections. A first section **71** is adapted to be received by the coupling **80** and secured thereto by interference fit, chemical bonding, mechanical bonding (e.g. pinning), or cooperating threading. The second section **72** is sized to be received inside a cooperating chamber and to be movable within the chamber for dispensing or aspirating a first volume of fluid. FIGS. **6**D–**6**F show a second piston **170**. Piston **170** has a substantially uniform size. A first section of piston **170** is installable within the coupling **80** and secured thereto by interference fit, chemical bonding, mechanical bonding (e.g. pinning), or cooperating threading. The second section of piston **170** is insertable within a cooperating chamber and provides for aspirating and dispensing a second volume of fluid which is smaller than the first volume of fluid. A third piston is shown in FIGS. **6**G–**6**I. Third piston **270** also includes two differently sized sections. A first section **271** is adapted to be received by the coupling **80** and secured thereto by interference fit, chemical bonding, mechanical bonding (e.g. pinning), or cooperating threading. The second section **272** is sized to be received inside a cooperating chamber and to be movable within the chamber for dispensing or aspirating a third volume of fluid which is larger than the first volume of fluid. While each piston is shown having a single sized second section, the second section could be configured wherein the second section has a first part and a second part, the first part having a narrower diameter than the second part, resulting in a stepped piston.

FIGS. **7**A–**7**C show a split hub clamp nut **60**. Split hub clamp nut **60** includes a first central bore **61** and a slot **62** extending from bore **61** to an external surface of the split hub clamp nut **60**. Split hub clamp nut **60** further includes a second bore **63** for receiving a locking screw therein. The split hub clamp nut **60** is installed surrounding a portion of the anti-backlash leadscrew follower and the leadscrew. Once the split hub clamp nut **60** is installed surrounding the anti-backlash leadscrew follower, a locking screw is installed within the bore **63** and tightened to secure the split hub clamp nut in place. The split hub clamp nut **60** is rotatable by a user via the side opening in the housing. The user can manually rotate the split hub clamp nut **60** and move the position of the piston to a desired location within the chamber.

Referring now to FIGS. **8**A and **8**B nut **50** is shown. Nut **50** is used to removably secure a chamber to the housing. Nut **50** includes a central bore **51** that is threaded and mates with a cooperating portion of the housing seal. Nut **50** also includes a second bore **52** that captures a portion of a chamber therein.

Referring now to FIGS. **9**A-**9**F three seals **470**, **570** and **670** are shown. Each seal attaches to housing **30** at a first end and threadably receives nut **50** at a second end. Seal **470** includes a first bore **471** for receiving a portion of chamber **40** therein. A second bore **472** receives a portion of piston **170** therethrough. A third bore **473** receives a portion of coupling **80** therein. FIGS. **9**C–**9**D show a seal **570**. Seal **570** is similar to seal **470** except that the second bore is sized to receive piston **70** therethrough when piston **70** is used. Similarly, a third seal **670**, shown in FIGS. **9**E–**9**F, is similar

to seal **470** except that second bore is sized to receive piston **270** therethrough when piston **270** is used.

FIGS. **10**A–**10**C show coupling **80**. Coupling **80** includes a shutter **81** extending from an outside surface of coupling **80**. Coupling **80** further includes a bore **84** for receiving a pin **85** therethrough. Pin **85** is received within the slotted openings **36** of each of the anti-rotation guides **34** of the housing **30**. Pin **85** slides within the anti-rotation guides and prevents coupling **80** from rotating while the coupling is being driven forward and/or backward within the housing. Coupling **80** has a first central bore **82** extending partially within the coupling. First central bore **82** is sized to receive a portion of the piston therein. A second central bore **83** extends from an opposite end of the coupling as first central bore. Second central bore **83** receives a portion of the leadscrew **90** therein. Coupling **80** thus couples the leadscrew **90** to a piston.

FIGS. **11**A–**11**B show leadscrew **90**. Leadscrew **90** has two sections, a first section **91** having a first diameter and a second section **92** having a narrower diameter than first section **91**. First section **91** couples to the motor **20**, while second section **92** is received within the coupling **80**.

FIGS. **12**A and **12**B show a spring **160** that is used as part of an anti-backlash leadscrew follower assembly. FIGS. **13**A and **13**B show anti-backlash leadscrew follower **100**. FIG. **14** shows the anti-backlash leadscrew follower **100** installed on leadscrew **90** with spring **160**. The anti-backlash follower **100** is self-aligning as it fits into a hollow portion of the shaft and is secured to the shaft, as well as being spring loaded by spring **160** to provide a biasing force against the leadscrew **90** to account for any tolerance differences with the leadscrew **90** and to account for dimensional changes as the leadscrew to follower nut junction wears.

FIGS. **15**A–**15**C show assemblies wherein the leadscrew **90** has the anti-backlash leadscrew follower **100** and spring **160** installed. The leadscrew **90** is coupled to coupling **80**, and coupling **80** is coupled to the piston **70**, **170**, **270**.

FIGS. **16**A–**16**C show mounting plate **159**. Mounting plate **159** comprises a base plate **162** and four mounting posts **161**. The housing is secured to the posts **161** by screws or other fasteners that are received through mounting holes on the housing and into the posts **161**.

The above described precision pump by way of the integral anti-rotation guides, anti-backlash leadscrew follower, the end play locknut of the stepper motor, and the fine pitch leadscrew coupled to the stepper motor, provides for accurate and reliable aspirating and dispensing of fluid. The inclusion of self-aligning parts and the reduction in the number of parts provides substantial cost savings in the manufacturing of the precision pump since assembly time and alignment time are minimized or eliminated. Further, the precision pump is easily changed to aspirate and/or dispense different volumes of fluid by removing a cooperating piston and chamber of a first size and installing a cooperating piston and chamber of second different size.

Having described preferred embodiments of the invention it will become apparent to those of reasonable skill in the art that other embodiments incorporating the above described features may also be developed. Accordingly, it is submitted that the present invention not be limited to the described embodiments but rather by the scope and spirit of the appended claims.

We claim:

1. A precision pumping device comprising:

a housing including an integral anti-rotation guide;

a first chamber removably coupled to said housing;

a first piston displaceable within a portion of said chamber, said first piston and said first chamber adapted to aspirate or dispense a first volume of fluid;

a port disposed within said chamber, said port providing fluid communication from within said chamber to outside of said chamber;

a fine pitch lead screw;

a coupling fixedly linking said piston to said leadscrew;

an anti-rotation member projecting from said coupling and into said anti-rotation guide;

a split hub clamp nut coupled to said leadscrew; and

a stepper motor attached to said housing, said stepper motor coupled to said leadscrew and operative to move said leadscrew in a first direction for moving said piston within said chamber to dispense a first volume of fluid within said chamber out of said port, said stepper motor operative to move said leadscrew in a second direction for moving said piston within said chamber to aspirate a first volume of fluid into said chamber through said port.

2. The precision pumping device of claim **1** further comprising an anti-backlash leadscrew follower coupled to said leadscrew.

3. The precision pumping device of claim **2** wherein said anti-backlash leadscrew follower is self-aligning.

4. The precision pumping device of claim **2** wherein said anti-backlash leadscrew further comprises a spring providing a biasing force between said leadscrew and said coupling.

5. The precision pumping device of claim **1** further comprising a seal disposed around said piston and against a surface of said chamber.

6. The precision pumping device of claim **5** further comprising an o-ring disposed within said chamber and against a flange of said seal.

7. The precision pumping device of claim **1** further comprising an end play lock nut disposed on an end of said stepper motor.

8. The precision pumping device of claim **1** further comprising a nut removably coupling said chamber to said housing.

9. The precision pumping device of claim **1** further comprising at least one additional port disposed in said chamber.

10. The precision pumping device of claim **1** wherein said housing comprises LEXAN having TEFLON filler.

11. The precision pumping device of claim **1** further comprising:

a second piston having a different size than the first piston, said second piston substitutable for said first piston; and

a second chamber having a different size than said first chamber, said second chamber substitutable for said first chamber, said second piston and said second chamber adapted to dispense or aspirate a second volume of liquid.

* * * * *